



## Silicon/Carbon Nanotube Photocathode for Splitting Water

The combination of materials is expected to increase the efficiency of the redox reaction.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proof-of-concept device is being developed (see figure) for hydrogen gas production based on water-splitting redox reactions facilitated by cobalt tetra-aryl porphyrins (Co[TArP]) catalysts stacked on carbon nanotubes (CNTs) that are grown on n-doped silicon substrates. The operational principle of the proposed device is based on conversion of photoelectron energy from sunlight into chemical energy, which at a later point, can be turned into electrical and mechanical power.

The proposed device will consist of a degenerately n-doped silicon substrate with Si posts covering the surface of a 4-in. ( $\approx 10$ -cm) wafer. The substrate will absorb radiation, and electrons will move radially out of Si to CNT. Si posts are designed such that the diameters are small enough to allow considerable numbers of electrons to transport across to the CNT layer. CNTs will be grown on top of Si using conformal catalyst (Fe/Ni) deposition over a thin alumina barrier layer. Both metallic and semiconducting CNT will be used in this investigation, thus allowing for additional charge generation from CNT in the IR region. Si post top surfaces will be masked from catalyst deposition so as to prevent CNT growth on the top surface.

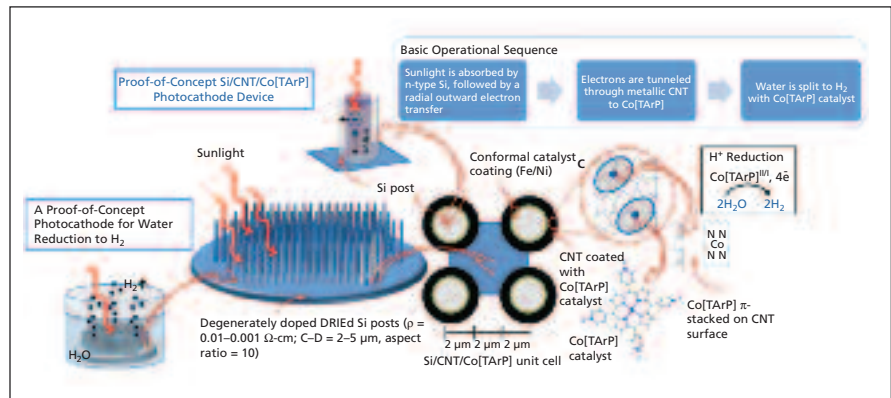


Diagram and basic operational sequence of the proof-of-concept Si/CNT/Co[TArP]. The bioinspired catalyst, Co[TArP], lowers the activation barrier for the photoactivated water splitting reaction. Rapid electron transfer from degenerately doped Si posts to metallic CNT enables the water reduction reaction. CNT material serves not only as an excellent "wire" for the electron, but as an unsurpassed substrate for the catalyst, since the mechanism ( $\pi$ -stacking) by which it binds Co[TArP] does not lead to significant changes in catalytic activity. The unique combination of Si, CNT and Co[TArP] is a very promising approach with a high potential to become a major breakthrough in the field of photocatalytic water splitting research and technology areas.

A typical unit cell will then consist of a Si post covered with CNT, providing enhanced surface area for the catalyst. The device will then be dipped into a solution of Co[TArP] to enable coating of CNT with Co(P). The Si/CNT/Co[TArP] assembly then will provide electrons for water splitting and hydrogen gas production. A potential of 1.23 V is needed to split water, and near ideal

band gap is approximately 1.4 eV. The combination of doped Si/CNT/Co[TArP] will enable this redox reaction to be more efficient.

*This work was done by Xenia Amashukeli, Harish Manohara, Harold F. Greer, Lee J. Hall, Harry B. Gray, and Bryan Subbert of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-46951*

## Advanced Materials and Fabrication Techniques for the Orion Attitude Control Motor

Rhenium is ideally suited for high-temperature applications.

Marshall Space Flight Center, Alabama

Rhenium, with its high melting temperature, excellent elevated temperature properties, and lack of a ductile-to-brittle transition temperature (DBTT), is ideally suited for the hot gas components of the ACM (Attitude Control Motor), and other high-temperature applications. However, the high cost of rhenium makes fabricating these components using conventional fabrication

techniques prohibitive. Therefore, near-net-shape forming techniques were investigated for producing cost-effective rhenium and rhenium alloy components for the ACM and other propulsion applications.

During this investigation, electrochemical forming (EL-Form™) techniques were evaluated for producing the hot gas components. The investiga-

tion focused on demonstrating that EL-Form processing techniques could be used to produce the ACM flow distributor. Once the EL-Form processing techniques were established, a representative rhenium flow distributor was fabricated, and samples were harvested for material properties testing at both room and elevated temperatures. As a lower cost and lighter weight alterna-